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# Measurements of the surface diffusion coefficient in iron-carbon alloys using Focused Ion Beam milling and High Temperature Laser Scanning Confocal Microscopy

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# Measurements of the surface diffusion coefficient in iron-carbon alloys using Focused Ion Beam milling and High Temperature Laser Scanning Confocal Microscopy

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The use of high-temperature confocal microscopy, shows a great potential as a means of measuring surface diffusion coefficients in metallic systems[1]. This new experimental approach has an advantage as contaminants entering the system are significantly reduced. Surface diffusion coefficients can be determined at temperatures approaching the melting point.

Mullins and King[2-5] have shown that surface undulations can be related to the surface diffusion coefficient of a metal. In this study, focused ion beam (FIB) milling has been used to introduce geometrically well-defined undulations on the surface of iron and iron carbon alloys (see **figure 1 A**). High temperature laser scanning confocal microscopy was then used to observe the decay *in situ* in real time (**figure 1 B**).

The confocal microscope scans the surface giving a surface-amplitude and width scale. The surface undulations and amplitude are observed to decay at various rates (**figure 2 A**). When the groove width broadening with respect to time is plotted for a given temperature the surface diffusion coefficient can be determined as in **figure 2 B**. The diffusion coefficient $D_s$ can be derived from the equation $w = 6.9Bt^{1/4}$, where $t$ is the time in seconds and $B = \frac{D_s \gamma \Omega^{4/3}}{kT}$. Here, $\gamma$ is the surface energy of iron, $\Omega$ is the atomic volume of iron in the lattice, $T$ is the temperature and $k$ is Boltzmann's constant.

The high temperature furnace in the confocal microscope operates in an inert atmosphere and a very low oxygen partial pressure is maintained. This technique rendered surface diffusion rates for carbon steel to be of the order $10^{-10}$ $m^2s^{-1}$, compared to $10^{-8}$ $m^2s^{-1}$ for pure iron above the eutectoid temperature.

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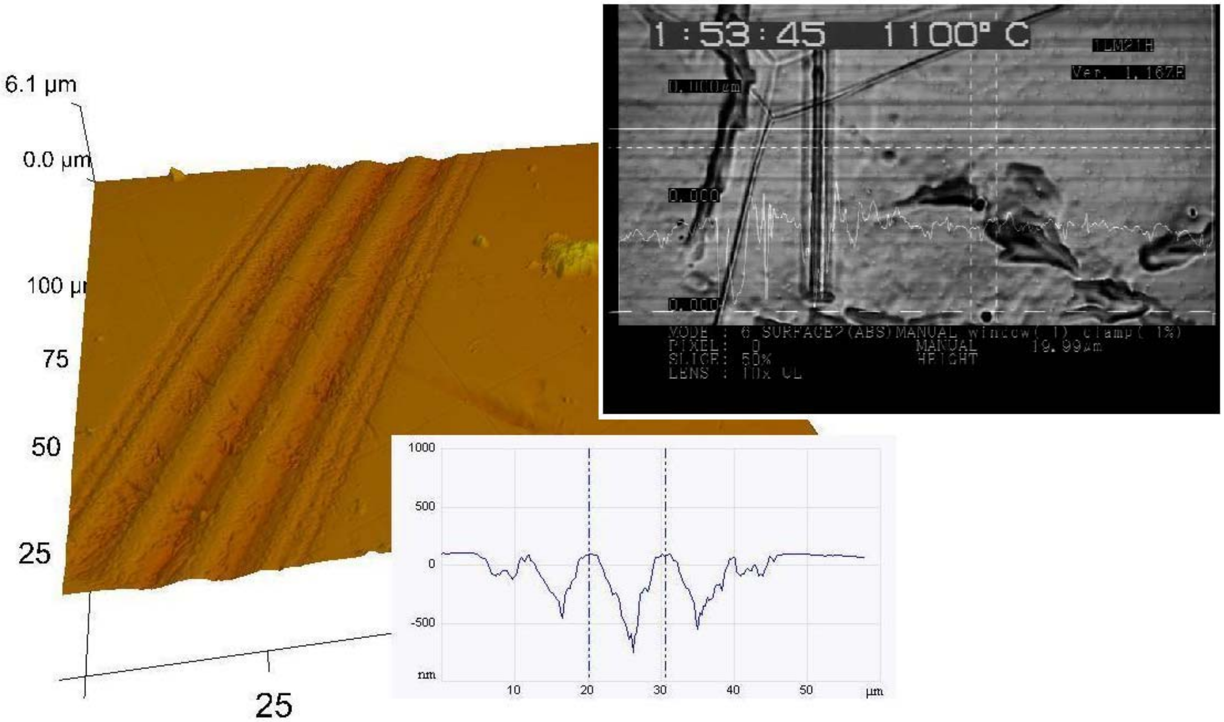
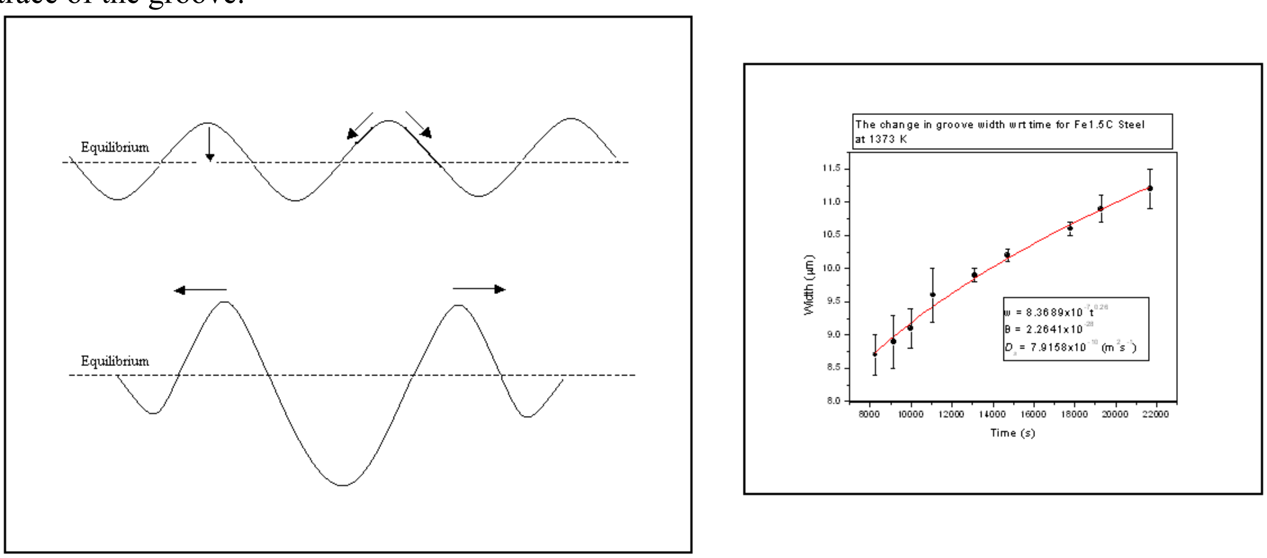



**A.** **B.**

**Figure 1:** (A) A 3D AFM image of a surface groove created in the focused ion beam mill. Inserted is a section view of the depth. (B) The confocal microscope image of the surface showing the scope trace of the groove.




**A.** **B.**

**Figure 2:** (A) A schematic representation of a surface groove decaying. (B) A graph of the groove width decay with respect to time.